DOCUMENT RESUME

ED 228 304 TM 830 225

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TITLE Processing and Interpreting Spatial Information Represented Graphically.
PUB DATE Apr 83
NOTE 34p.; Paper presented at the Annual Meeting of the American Educational Research Association (67th, Montreal, Quebec, April 11-15, 1983).
PUB TYPE Speeches/Conference Papers (150) -- Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Processes; Diagrams; Graphic Arts; Imagery; Instructional Design; *Layout (Publications); Learning Processes; *Material Development; *Visual Learning
IDENTIFIERS *Graphic Representation; Physical Properties

ABSTRACT

This paper proposes that three properties of graphic materials can be manipulated by instructional designers to model cognitive processes and thus help students learn. These properties are: the distance of elements in the graphic display from each other, the orientation of the elements to each other, and the sequence in which the elements are encountered. Research from the last 15 years regarding these properties is surveyed and discussed. Studies of imagery, the symbolic distance effect, eye movement, semantic distance, and diagrams are included. The survey presents evidence for parallels and analogies between the form of graphic material that is presented to or imaged by learners, and the way it is processed. This leads to the conclusion that the form graphic materials take influences the learning strategy that the learner uses more than the form of internal representation. (Author)

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# Processing and Interpreting Spatial Information Represented Graphically.

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Paper presented at the annual conference of the American Educational Research Association, Montreal, April, 1983.

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## Introduction

Scholars have identified numerous properties of graphic materials. This paper proposes that a subset of these properties, to do with the arrangement in space of graphic elements can be manipulated so as to model cognitive processes and forms of representation. The properties to be discussed are: the distance of elements from each other; the orientation of elements to each other; the sequence in which the elements are encountered. Such properties as realism, size and color will not be discussed.

The thesis of this paper is that the relatively abstract nature of graphic materials (when compared to realistic pictures) requires that they often be processed propositionally, not exclusively as mental images. This means that relationships between graphics and internal representations and processes are sometimes analogical rather than literal. For example, Washington might be placed to the left of Lincoln on a time scale illustrating the order of American presidents. However, the relative placement of the two presidents is interpreted analogically within the convention, determined by the way we read and write English, that "to the left of" means "first in order". Similarly, placing "cat" closer to "dog" than to "aardvark" in a tree diagram illustrating the animal kingdom is an analogical

representation of the "semantic distances" among the three concepts as they are to be represented in memory.

The paper reviews research selected from the last fifteen years into relationships between the three properties of graphics and learning. It deals with the effects both of instructional materials and of mental images that possess the same spatial properties of distance, orientation and sequence. Inducing learners to form such images is often a successful instructional strategy. Included are studies on diagrams, imagery, the symbolic distance effect, semantic networking, and eye movement. These studies show that variation in distance, orientation and sequence in graphic materials has an influence on how the information they convey is processed and interpreted. What is more, when instructional designers fail to control these properties of graphic materials, learners will impose their own structure and interpretation which may be quite erroneous. The paper concludes with some suggestions as to how these four properties can be used to good effect by instructional designers.

## Some Basic Assumptions.

We will now look at some assumptions about learning and graphic materials that underlie the discussion that follows. The first assumption is that graphic materials, like any visual

materials, convey meaning in two ways. The first of these is through the pictorial elements they contain. The second is through the patterns and sequences formed by the placement of the elements on the page. Knowlton (1966) was one of the first to propose this. He distinguished between the elements of a picture, their pattern and their order of connection. For example, in a map, information is conveyed by the conventional signs, which comprise the "elements" of the visual display. A black square with a cross on top means that a church is to be found in that location. Information is also conveyed by the patterns that these conventional signs form. The map will tell us that the church is to the north of the radio tower and about half way between it and the river. Finally, information is also conveyed by the sequence in which one would encounter features represented by conventional signs if one were to walk along a particular route. Thus, we would know that going from the radio tower to the river, we would encounter first a railroad, then the church, then a crossroads, and finally the river. Thorndyke and Hayes-Roth (1982) make a similar distinction. They conclude from their study that maps allow people to encode spatial information that can be scanned and measured like a physical map. The act of "navigating" particular terrain, on the other hand, provides procedural knowledge about the route that connect the various locations together. It is important that the ability to convey sequence in a map, or in any graphic come to that, does not depend to any great degree on the realism of the elements nor on

whether the pattern of elements is to scale or even all that accurate.

The influence that graphic materials have upon cognitive processing and internal representation depends upon the nature of each of the elements in a graphic, the pattern that they form, and the sequence in which they are encountered under a given set of circumstances. A great deal of research has been done regarding the first of these. This research would include the study of the effects of pictorial realism, color and cueing upon learning (Dwyer, 1972, 1978). This paper is concerned with the last two features of graphics and graphic images, areas in which less research has been completed, involving how people perceive and derive meaning from the patterns that elements form in graphic material and images, and how the sequence in which they peruse the elements influences their interpretation of them.

The second assumption is more contentious, for it involves the "imagery versus proposition" debate, (See Pylyshyn 1973, 1981; Anderson, 1978; Kosslyn, 1980, 1981). The position taken in this paper is that, in order to be processed "mindfully", to use Salomon's (1981) term, graphic materials and images need to be stored and processed as propositions. This means that they are translated, through a process of abstraction, until they lose any "realistic" qualities that they might have had when encountered in materials by the learner (Winn, 1980). This abstract quality

of propositions is a necessary endowment of information derived from graphic materials if it is to be amenable to the mental manipulation required for its assimilation to schemata, its association with other information in memory, and its translation into other forms, should retrieval from memory require it (Winn, 1982).

This may seem to contradict the statement made above that mental images having the same properties as graphics can influence learning. However, the function of such images in learning is limited in the same way as the function of graphic materials. That is to say, they too need to be translated and abstracted in order to become useful to the learner. Any advantages that accrue from them derive from initial and relatively superficial processing.

A number of studies support the contention that visual information is encoded propostionally if it is to be manipulated (see Anderson and Paulson, 1978; Mani and Johnson-Laird, 1982, and the numerous studies discussed by Anderson and by Pylyshyn in the reviews cited above). Evidence offered in support of imaginal encoding of visual information (Kosslyn, 1980, 1981), is derived from experiments in which the tasks were qualitatively different from those providing support for propositional representation. By and large, the former tend to involve relatively "superficial" cognitive processes, such as scanning. Processes like these are

essential first steps in interpreting information. But the assimilation of that information to schemata, and its further organization, require "deeper" processing involving abstraction and translation.

The third assumption is that graphic materials can function as embedded strategies (Rigney, 1978). This means that they implicitly indicate to the learner an appropriate learning strategy and/or explicitly model cognitive processes that the learner would do well to employ. This suggests that the patterns and sequences of graphic materials have their greatest influence upon learning at the level of the cognitive strategy the learner uses, and not through the form in which the information they convey is represented in memory. This is an extremely important point, and has considerable bearing upon the design of graphic materials for instruction.

For the purposes of this paper, we shall assume that the learners are capable of performing the cognitive skills required by a particular learning strategy. We will not be much concerned with how these skills can be developed in learners who are deficient in them.

We will now look at research dealing with the three properties of graphic materials, namely distance among elements, orientation, and sequence.

Distance among elements.

The metaphor of semantic "distance" goes back a long way in psychological research. It proposes that the organiztion of concepts in memory can be described in terms of the apparent distance of one to the next. In everyday language, we make statements to the effect that one thing is "closer to" another than to a third. For instance, students might feel that physics is closer to chemistry than it is to English literature, or that hurdling is closer to sprinting than to the high jump. Such judgments of proximity are made upon the basis of the number of features that are considered to be common to each of the concepts being compared (Tversky, 1977).

Originally, the metaphor of semantic distance was employed descriptively. The structure of concepts in a particular domain was described in terms of interconcept distances derived usually from subjects' free associations to the concepts in the domain (Deese, 1962, 1965; Garskoff and Houston, 1963). A parsimonious and interpretable description of the structure of the conceptual domain was arrived at by means of factor analyzing, or scaling, matrices of coefficients expressing the strength of the relationship, in terms of the number of common free associations, between every possible pair of concepts. In this way, subgroups of concepts could be observed to form clusters, separated in

space from other clusters, each having a common fundamental semantic property.

Semantic distance has subsequently been used, primarily by researchers in science teaching, in instructional research. Shavelson (1972) developed a technique for representing prose as directed graphs (Harary, Norman and Cartwright, 1965). Then, by counting the number of nodes of a graph lying between two concepts, Shavelson was able to estimate the semantic distance between them. A matrix was constructed in which were placed the distances, calculated in this way, between all possible pairs of concepts in the text passage. In his experiment, Shavelson taught Newtonian mechanics over a period of several weeks and periodically had his students give free associations to the concepts they were learning. He found, when he compared the empirically derived free association matrices with those derived from analysis of the text, that the euclidian distances between them declined. In other words, the conceptual organization the students constructed in memory became increasingly similar to the actual organization of the content in terms of semantic distance. Similar results have been reported by Preece (1976) and Thro (1978).

A directed graph, or any form of "map" of a conceptual domain, could serve as an instructional graphic, for it captures both the pattern of the elements (concept labels in Shavelson's

case) and the sequence in which they might be encountered. This idea was pursued in a study by Winn (1980), where an instructional diagram describing food chains was constructed directly from a map of the content. It was found that students who were taught with this diagram were more successful in organizing the content in a way similar to that derived by mapping than those who read a text of the same content. The effect was more noticeable in the case of high-ability learners. This study suggested that diagrammatic representation of semantic distances does indeed influence the way students organize conceptual domains.

We cannot leave this topic without noting Tversky's (1977) objections to the idea of rating similarity in terms of "metric distances" among concepts. Tversky bases his objections upon two findings from his own experiments. First, similiarities are often assymetrical. North Korea was rated more like Red China than Red China was rated like North Korea. Second, similarity is not transitive. Jamaica is similar to Cuba (because of its location in the Carribean). Cuba is similar to Russia (because of its politicial system). But Jamaica is <u>not</u> rated similar to Russia. Tversky concludes that it is preferrable to rate similarity on the basis of common features, not distances.

In response to Tversky's objections, it can be argued that he appears to have taken the metaphor too literally. Indeed, in a

specific comment on Tversky's paper, Ortony (1979) argues for a modification to include "metaphoricity", thus considering the relative salience of attributes of concepts that are to be judged for their similarity. A related point is made by Krumhausl (1978) in another reply to the Tversky paper. Krumhausl argues that similarity of objects is a function not only of inter-object distance, but also of the "density" of objects in the surrounding configuration. This suggests that the context of each concept be taken into account. Thus, neither in the political nor in the geographical context is Jamaica like Russia, so in this example, transitivity is irrelevant.

This is not really the place to pursue the issue further. Let us simply note that there is evidence that instruction appears to create conceptual structures in learners that resemble content structures, and that graphic materials created to represent maps of interconcept distances do enable learners to construct conceptual domains in which the actual distance on the page has been translated into semantic distance which encodes information about how one concept relates to the next.

A second area of research in which actual distance has been shown to be related to processing and representation is concerned with the "symbolic distance effect" (Mayer and Landauer, 1967; Holyoak and Walker, 1976; Holyoak, 1978). The proposition underlying this research is that certain types of information,

such as numbers and letters, which are not usually associated with real distance, can be represented as linear mental arrays which are scanned by the subject (Mayer and Bayer, 1978). In a typical experiment (Holyoak, 1978), reaction times for judging "which is bigger, three or four" were slower than for making the same assessment of three and nine. This is because there would be a greater "distance" between three and nine in a linear mental array than there would be between three and four, making the difference easier to "see". The implication is that information, which is initially represented as a mental image, can be scanned just as a picture can be, and that estimations of conceptual distances can be made if the conceptual domain can be expressed as an image. What is more, estimates of distances between two points depend on their proximity to a given reference point (Holyoak and Mah, 1982), or on the number of elements intervening between them (Thordyke, 1981). Thus, the symbolic distance effect, like judgments of similarity, is prone to influence by context and other points of reference.

There is an obvious link between this research and Kosslyn's studies (summarized in Kosslyn, 1980) where subjects performed a number of mental operations on images, including scanning, and as well with Holyoak's (1977) and Paivio's (1975) research on reaction times for making judgments of relative size. What is of importance for us, though, is the close link between mental images of concepts in arrays, with definite distances among thee

elements, and the representation of such concepts as arrays on paper or on the screen. What Holyoak's (and Kosslyn's) research suggests is that symbolic distance among concepts not usually associated with distance, affects the way they are processed and understood.

Orientation of elements

Researchers have known for a long time that the relative orientation of elements in a visual display one to another has meaning and can affect learning. An early illustration of this is the research of Chase and Simon (1973) on chess players. Their finding that chess masters can recall "meaningful" board positions better than boards on which the pieces have been placed arbitrarily, while novices recall either board set-up equally well, suggests that patterns of elements can be meaningful, and that the better a pattern fits an existing schema, the better it will be recalled. Similar results have been reported for other board games (Eisenstadt and Kareev, 1975).

Another, and somewhat esoteric, area of research is exemplified by attempts to describe schemata derived from visual information in terms of predicates expressing orientation of one element to another. An example is given by Palmer (1975). He suggests that a face might be stored as a proposition in which

each element (eye, nose, mouth, etc.) is related to the other in terms of its angle, size, shape, direction, and so on. Thus, the left eye would be represented in memory as having roughly the same general shape as the head, rotated through ninety degrees, about one eighth its size, and located above and to the left of the nose. While such a model is intriguing, and certainly thorough, it does seem unnecessarily cumbersome, especially given that propositional representation is characterized by a degree of abstraction.

Our primary interest in this paper, however, is with less esoteric issues. Again, we are concerned mainly with the ability of graphic representation to help learners organize and process relationships that are largely symbolic, just as conceptual distance is.

An area that has received some attention is the graphic representation, either mental or actual, of syllogisms in order to facilitate their solution. A typical experiment was conducted by Sternberg and Weil (1980). Subjects were trained to solve syllogisms of the type "John is bigger than Bill, Bill is taller than Pete, who is the tallest?" using one of two strategies. In the visualization strategy, subjects were told to try to visualize the elements of the syllogism in a spatial array, so that the tallest might be placed at the top, and the shortest at the bottom of an imaginary page. The second strategy involved

the application of an algorithm of the type "If the answer contained in the first statement is not contained in the second, then the answer is ... " A third group served as a control group, and was given no strategy. The dependent variable was response latency and accuracy. The results showed some main effects and an ATI between verbal and spatial ability, type of strategy, and response latency. Interestingly, the majority of subjects used a "mixed" strategy, involving both visual and algorithmic techniques.

This study suggests that mentally representing an abstract problem, such as a syllogism, in "graphic" form does affect the speed of its solution. The same is true for the graphic layout of a syllogism on the page. In a similar study, Johnson-Laird and Steedman (1978) found that the form of a syllogism on the page biases its solution when there is more than one possible right answer. Their conclusion, that the syllogisms "receive an analogical mental representation that captures their logical properties structurally" could well be applied to all studies of this type.

So far, we have looked mainly at mental representation that is spatial. The graphic materials that most obviously take advantage of the spatial orientation of elements within them are diagrams. By and large, the instructional effectiveness of diagrams can be attributed precisely to their encoding of

conceptual information spatially rather than syntactically as in the case of prose (Winn and Holliday, 1982). The meaningfulness of this placement on the page involves either the creation of patterns to assist classification, or to help students learn cycles and sequences. In the former instance, we are talking about block diagrams, and in the latter we are dealing primarily with flow diagrams.

Research into the effectiveness of block diagrams (Winn, 1980, 1981; Holliday and Benson, 1981) has generally led to conclusions concerning column and row headings and assigning concepts to superordinate categories. For example, Winn (1981) found that students who saw a slide set in which a chart showing stages of metamorphosis for different types of insect performed better on a test requiring them to classify the animals by type and by type of metamorphosis than students who saw a slide set in which critical attributes of each insect were highlighted. The column headings (dragonfly, mayfly, butterfly and fly) and the row headings (egg, larva, pupa, adult) established a simple two-way classification scheme which the boxes in the four by four matrix filled in. Presumably, the learners knew from previous experience that when one sees a simple two-way matrix with row and column headings the concepts occuring in the rows and columns are subordinate to the concepts named by the headings, and that each subordinate concept has a place in both superordinate categories. One might say that the learners have become "diagram

literate", or that they have a well-established block diagram schema that leads them to anticipate certain information that is dependent for its meaning on its placement relative to the boxes of the matrix or to the headings.

In the case of flow diagrams, the spatial orientation of the elements to each other has two functions. The first is the placement of elements in the diagram in locations that correspond to their occurrence in the real world. For instance, in a flow diagram illustrating bigeochemical cycles (Holliday, 1976; Holliday, Brunner and Donais, 1977), such concepts as "the oxygen cycle" and "fixation through lightning" occur high on the page in a location that corresponds to the sky, where they do in fact occur. On the other hand, "bacteria of decay" and "fossil fuels" are found low down in positions that would correspond to locations below ground level. (The effectiveness of these spatial placements is improved when the flow diagram includes a number of realistic pictures in place of words naming each concept. The realistic depiction of clouds and tree roots reinforces the location of the various elements relative to each other.)

The other important feature of flow diagrams is the way they present sequences of concepts, which may be linear or cyclical. Again, in the same studies by Holliday, the cycles that the diagrams illustrate are shown as circles of concept labels

connected by curved arrows. It does not matter where the learner begins. The starting point will always recur as one continues through the sequence of concept names. And it is precisely this point that is crucial to a student's understanding of biogeochemical cycles. What is more, the cycles quite literally revolve around a central concept, which is "the plant", and which is found in the center of the page. The placement of the plant relative to all the other elements in the diagram focusses the student's attention on it thus stressing its importance in comparison to the other concepts in the diagram.

Thus, in both types of diagram, we can see that the relative orientation of each element to the others has an influence on how they will be processed. In the case of block diagrams, placement of names of concepts in rows and columns indicates to the learner that they are to be classified into certain categories. In flow diagrams, the absolute placement of elements on the page (high or low), and their placement in cycles or sequences, conveys information about sequences of events in processes, and even about causality, without it having to be spelled out in lengthy text. Also, the placing of some concepts around another central one suggests to the learner that this is the "central" concept "around" which the others "revolve".

Emerging from this research is the underlying idea that the general overall form of the graphic is itself meaningful, and

determines in large part how the information it contains will be processed. This idea ties in with schema theory (Neisser, 1976), where schemata direct search and lead learners to anticipate what they will find in instructional materials. Thus, the block diagram, with its matrix, rows and columns, will activate a schema leading the learner to anticipate concepts belonging to categories. The flow diagram, in which concepts appear to "float" around a central concept in a series of cycles, will activate a schema leading the learner to anticipate sequential and cyclical processes. If, as Navon (1977) has suggested, we perceive the general in what we view before the particular, then this has important implications for instruction. The overall impression that is initially created about the relative orientation of elements within graphic materials will determine in large part how the individual elements and the details of their relationships one to another in space are perceived and interpreted. On the other hand, the general form created by the pattern of the elements can be used to advantage by the designer to activate a general though relevant schema (to serve in fact as an advance organizer) into which the learner will be able to assimilate the information that is presented. Obviously, the activation of a block diagram schema will have a different effect from the activation of a flow diagram schema.

Sequential organization

We have already talked a little bit about the interpretation of sequences of elements in flow diagrams. This portion of the paper will be confined to a discussion of two studies which set out specifically to study the matter of the sequential organization of elements in graphics.

In the first study (Winn, 1982), two horizontal tree diagrams were prepared that illustrated the evolution of dinosaurs. In the first, the animals were shown evolving from left to right across the page, with a time scale at the top of the page. Superordinate category headings were included (e.g. "duckbilled", "carnivorous") to the left of the dinosaurs at appropriate places on the various "branches" of the tree. In the second diagram, everything was reversed. The animals evolved from right to left, with the time scale at the bottom, and the superordinate category names to the right of the animals. Grade nine subjects studied the diagrams and took tests requiring them to recall the sequence of evolution and the categories of dinosaur to which each belongs. As might be expected, subjects who saw the reversed diagram scored more poorly on the tests than those who saw the left to right diagram.

The results from this study were interpreted as supporting the hypothesis that people "read" diagrams in the same way that

they read text, from left to right and top to bottom. This meant that, when other cues are not sufficient to indicate the sequence in which the elements in graphic materials are to be scanned, then the left-right top-bottom habit pertains. However, it seemed that matters might not be as simple as that. A second study was conducted (Winn, 1982c) using the same diagrams with adults whose eye movements were monitored as they looked at the graphics.

The study tested a hypothesis, derived from research by Snow (1978) and Just and Carpenter (1976), that successful learners would follow a three-step strategy involving: orientation to the graphic, establishing sequential relationships among the elements, and making a decision which would lead to the accomplishment of a particular task. In this case, the task each time was to find the answer to a question requiring the location and relating of two elements, for example: "was Tyrannosaurus a duck-billed dinosaur?", "was Triceratops a Jurassic dinosaur?". After calibration of the equipment, subjects were asked the question and then shown the diagram (either normal or reversed). As expected, subjects who saw the reversed diagram found it more difficult to find the names of the concepts involved in each question, to determine in which direction from the first concept the second concept lay, and to make the link between the two concepts. What is more, it was found that both groups of subjects made more fixations in the top left quadrant of the diagram, even though this would be the least logical place to

start looking for subjects who saw the reversed diagram.

These results not only confirm the left-right top-bottom preference people have for processing sequences of elements in diagrams, but also suggest that disruption of the anticipated sequence can render normal and automatic perceptual strategies quite ineffective. Of particular interest was the difficulty subjects seeing the reversed diagram had deciding whether the second concept was to the left or right of the first. When asked if a dinosaur belonged to a particular age or not, subjects could find the name of the age quite easily on the time scale. However, knowing which direction was "old" or "recent" proved to be quite difficult with the reversed diagram.

Related to this, though, was an observation that some subjects seeing the reversed diagram arrived at a point where they suddenly realized that everything was "backwards". Often, they made a statement to that effect. Sometimes, the moment was evident from the scan patterns themselves. In any event, once this insight had been arrived at, the performance of subjects seeing the reversed diagram improved noticeably. What this suggests is that their original "flow diagram" schema had been replaced by a "reversed flow diagram" schema, which enabled them to proceed quite effectively to perform the tasks.

What all of this suggests is that where students start when

they look at a graphic, and whether the sequence of elements is scanned by them in the order and direction intended by the designer, can have a profound effect on their success at understanding the graphic.

## Conclusions

The research that has been described in this paper is a selection from a large number of studies that have described the impact of graphic materials and graphic images on processing and learning. The general conclusion can be drawn that the distances among elements in graphics, their orientation one to another and their sequence are all meaningful to learners who have the intellectual skills necessary for their interpretation. The issue of developing these skills was not discussed.

In particular, physical distance translates into conceptual distance, which leads to the structuring of conceptual domains in particular ways as a result of the formation of concept clusters. As instruction progresses, these structures and clusters become more sharply defined and more like the actual structure of the material that is being learned. The presentation of conceptual maps to learners as instructional graphics helps this process along, especially in the case of high ability learners. The orientation of one element to another (above, below, beside,

between, etc.) creates a pattern that is also meaningful. The initial perception of this pattern reveals its general form only. However, this is sufficient to activate schemata that will determine how the information in the graphic will be processed and remembered. The general shape of a block diagram will lead to classification, while a flow diagram will induce the learner to look for cycles or sequences. As the information is perceived and processed in more detail, the actual and relative placement of elements on the page will exert their influence. When one element follows another in a cycle, for example, cause and effect might be attributed by the learner. And the placement of concept labels relative to the frame of the graphic might indeed suggest that certain concepts occur "higher" or "lower" than others in the real world. Finally, sequences are sought that run from left to right and top to bottom. Elements in graphic materials will be interpreted to follow each other in this way unless other graphic devices, such as arrows, make it very obvious that a contrary direction is indicated.

We have also seen evidence that when learners create mental images in which problems or sets of concepts are represented in ways which, like actual graphic materials, make use of inter-element distances, patterns and sequences, similar effects on processing and learning are observed. Research on the symbolic distance effect and on solving syllogisms illustrate this. However, it should be stressed that the imaginal

representation is relatively superficial and usually quite fleeting. It serves to initiate mindful processing and does not mean that the information contained in the image is stored as an image in long-term memory.

Following from this is the conclusion that graphic materials and images affect the strategy learners use to process information rather than the form in which that information is stored. The "classification" schema, evoked by the learner seeing the general form of a block diagram, leads the learner to process it further by fitting concepts named in boxes into superordinate classes named by row and column headings. It does not direct the learner to remember the shape and size of the matrix of rows and columns. Similarly, presenting a syllogism in a certain way on the page indicates to the learner a strategy for its solution rather than a form in which its contents are to be remembered. It is in this sense that graphic materials serve as embedded instructional strategies and model the cognitive processes learners might use. A linear array models scanning, a block diagram models classifying, a sequence models chaining and the attribution of causality.

All of this has implications for the creation of graphic materials for use in instruction. The first point to remember is that in materials where the distances among concepts in graphics, their pattern and sequence have not been carefully thought

through and made apparent, learners will impose their own interpretations which will frequently be the wrong ones. This means that designers must give careful attention to the way in which the spatial aspects of graphic materials are handled. This goes beyond the care that is usually given to the elements themselves. Designers can turn this to their advantage, and use distance, orientation and sequence to work for the learners. Graphics should be prepared in which the relative distances among concept labels are exaggerated to stress the way in which they cluster. Patterns can be created that correspond to the way in which concepts are organized in the real world. Their general appearance can be made to activate schemata that will lead to appropriate learning strategies. Sequences can either be arranged naturally, left to right, or other graphic cues can be used to remove all doubt about the way in which the sequences are to run.

If designers and instructors realize that arrangement of the elements in graphics on the page or screen is itself meaningful, then they will have at their disposal a powerful instructional tool. Both learners and instructional designers will benefit.

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